Title: Technical Assistance for Remote Sensor Placement Related Projects for Structural Health Monitoring

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Intended for: Report

Issued: 2014-08-27

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Category: Engineering

Type: Individual Poster Presentation

LA-UR:

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The world's infrastructure is aging and many aspects are cost prohibitive to replace or even repair unless critically necessary. The standard way of determining if these repairs are critical or not is usually dependent on trained visual individual inspection. This process is very time consuming and costly considering the large areas and various structures that need to be monitored. A cost effective solution to this problem is to be able to monitor structures, such as roads, buildings, and bridges with remote sensors. Developing this solution provides some unique challenges such as sensor placement, types of sensors, energy needs for placed sensors, and data retrieval. As for the aspect of sensor placement, one method is to fly semi-autonomous Unmanned Arial Vehicles (UAVs) loaded with a sensor deployment mechanism to the structures so as to place the sensor and perhaps retrieve data from previously placed sensors as well. Many tests need to be run to determine the best UAV structure and deployment system to fulfill this task. It is hoped that through a multidisciplinary engineering scope the most effective process of monitoring the aging infrastructure can be developed.

The national infrastructure is aging and as such falling into a state of critical disrepair. Most of these structures, such as bridges need to be visually inspected on a bi-annual schedule. This can be costly and risky work for trained personnel to perform. It is important to develop more effective ways to address this problem. One solution proposed by the National Security Education Center (NSEC) at Los Alamos National Laboratory (LANL) is to install semi-independent sensor modules on bridges and other structures so as to provide data for analysis to determine structural anomalies that may indicate critical damage. There are four aspects to this process that require concentrated effort for development of the final product.

The first aspect to determining the integrity of any material is to determine if its structure deviates from optimal performance criteria and by how much. For this project we are studying different methods of sensing so as to find the precise data that is best for determining the different modes of failure in a variety of material. Ultrasonic and Laser detection have proven to be very effective in finding a variety of simulated deformations in various materials. In a process where ultrasonic transducers are temporarily mounted to an metal surface with prepared simulations of defects that could cause criticality in stress circumstances, the ultrasonic waveform is disrupted in a predictable way and detected by laser scanning.

In our testing we applied temporarily mounted transducers to a prepared sheet of metal. The transducers produced a detectable range of frequencies in the material; however, they had an exposed electrical hazard that would cause a mild shock if mishandled. I used a 3D printer and rendering software to create a shield guard that would allow free manipulation of the transducers for the testing process without reducing the significant frequencies. Due to the specific nature of 3D printing and the material used it was capable of providing an adjustable hollow structure with strength in such a way that it had minimal contact with the ultrasound producing part of the structure. It also provided enough strength to allow for a firm grasp while placing or manipulating the placement. This is an example of how a variety of support techniques can aid the final focus of a project.

The ultimate goal of the sensors is to provide accurate data that will enable proper decisions to be made regarding the safety of structures. How the sensors themselves will perform this task is evolving with the advancement of the understanding of what data is needed.

Small surface mount sensors can be capable of reading a variety of circumstances, both external and internal to the structure it is mounted to. Temperature, seismic, electric, magnetic, and even radiation readings are all examples of data that can possibly be retrieved from a sensor that may be necessary in determining if a structure is sound, but what does the sensor need in order to accomplish this? The sensor needs power.

There are a variety of ways to provide on board power accumulation and regulation methods that will ensure that the sensor is functional for the duration of its placement. We are exploring piezio electric techniques to gain self-sufficiency in diverse environments for sensing equipment. Solar and wind power options are also possibilities as well. However, if the data can be retrieved intermittently then another option exists. The same vehicle that mounted the sensor in the remote location can also be sent to retrieve the data and bring along a power source, light. If the UAV is outfitted with a small nondestructive laser, it can focus the laser on a photocollector on board the sensor. This temporary charge can allow for the energy needed to perform the data transmission.

In all its functions the sensor is dependent on the versatility of the UAV. We are testing the capability of a UAV to perform the variety of functions required in Structural Health Monitoring. First of all we are testing the ability of the UAV to navigate using an onboard computer as an AI autopilot so that it can self-correct during unforeseen flight hazards. This capability would make the UAV robust enough for use in inclement climates. We are also testing the UAVs ability to lift, maintain stability with shock, and accurately target and deploy a sensor. It requires many prototypes to be able to retrieve data to prove the functionality of the UAV. I built the frame for propeller testing equipment with tachometer as well as a skeleton frame with wiring and motors for one of the backup roto-copters.

The UAV cannot perform its job of placing the sensor without having an effective deployment method. It is possible for the computer to analyze the environment and assess the best location for a sensor. A gimbal mounted gas gun can allow for accurately aiming at the targeted location with the assistance of the onboard computer the gas gun can fire precisely enough to mount a sensor without destroying the package or damaging the surface it is to be mounted to. In order to be able to know the proper pressurization to fire the sensor tests must be performed. I built and mounted an Arduino controlled phototransistor tachometer to the end of one of the working prototypes. The Arduino code is planned out so as to trigger an interrupt when the projectile passes over the first phototransistor, causing a drop in voltage. This interrupt calls for the Arduino to grab the current time as a number from the onboard timer. When the projectile passes over a second phototransistor at a set distance from the first the Arduino code again will trigger an interrupt. The second interrupt with call for the Arduino to grab a second number from the timer. The next operation in the code is to calculate the difference in the numbers so as to gain the time elapsed in the distance traveled by the projectile. With this data we can determine what range of speed a projectile travels at different psi rankings for each test. This data set will ultimately allow for algorithms to be programed into the AI of the onboard computer.

One further function of the NSEC is to encourage engineering education and as such they hold a summer school session where students from all around the country can participate in projects with a variety of goals. During this summer session I participated as technical help with light fabrication as well as 3D design and 3D printing. I used and maintained a commercially purchased 3D printer. I aided the student teams by providing in house fast prototyping and consulting on design and scope. In the process I performed maintenance and repairs as needed for the equipment, thereby gaining extensive knowledge and experience in the craft of 3D printing. Some examples of my efforts are assisting with the design and creation of a 3D model used for Shock Suppression Tests in addition to a frame ring to hold etched graphene structure with low voltage electrical current for Tamper Evident Seal analysis. Ultimately many aspects of the summer school program are used to assist and further the over-arching goal of Structural Health Monitoring.

My work with the 3D printing design and fabrication was beneficial to many teams with many projects and many goals. The phototransistor tachometer will provide ongoing data from shot testing to analyze placement strategies for different sensor nodes. The final result of my efforts as a team member at the NSEC was that I was able to further the ongoing mission of the team at the NSEC and the science of Structural Health Monitoring.